IV. " The Mineral Constituents of Dust and Soot from various Sources." By Professor W. N. Hartley, F.R.S., and Hugh Ramage.

V. " Notes on the Spark Spectra of Silicon as rendered by Silicates." By Professor W. N. Hartley, F.R.S.

VI. " On the Conductivity of Gases under the Becquerel Rays." By the Hon. R. J. Strutt, M.A., Fellow of Trinity College, Cambridge. Communicated by Lord Rayleigh, F.R.S.

" An Attempt to Estimate the Vitality of Seeds by an Electrical Method." By Augustus D. Waller, M.D., F.R.S. Received January 28,—Read February 21, 1901.

The present observations form part of an extensive series of experiments by which I am engaged in verifying whether or no " blaze currents "* may be utilised as a sign and measure of vitality.

An inquiry of this scope necessitates superficial examination of many varieties of animal and vegetable matter, and the closer study of certain favourable test-cases.

I have selected as such a test-case, the " vitality " of seeds, and have chosen for my purpose beans (*Phaseolus*) which are anatomically convenient and practically easy to obtain of known age.

But before entering upon the results in this particular test-case, I think it advisable to preface those results by a brief indication of the principle involved in all such experiments.

The method of investigation is similar to that adopted in the case of the frog's eyeball,* the complications of the principle and a tentative explanation of such complications is reserved for future discussion in a more comprehensive memoir.

By " blaze current " (the term which I was led to adopt by the study of retinal effects) I mean to denote the galvanometrical token of an explosive change locally excited in living matter. An unequivocal blaze current electrically excited is in the same direction as the exciting current, *i.e.*, it cannot be a polarisation counter-current. (An equivocal blaze current, in the contrary direction to the exciting current, *i.e.*, not at first sight distinguishable from a polarisation counter-effect, also exists, but is not taken into consideration in this communication.)

* A. D. W.—" On the ' Blaze Currents ' of the Frog's Eyeball," ' Roy. Soc. Proc.,' vol. 67, p. 439, and ' Phil. Trans.,' 1901.

Although the theoretical explanation of these currents is not now in question, it may here be remarked that the unequivocal or homodrome blaze current is probably of local post-anodic origin (the previously anodic spot being now strongly electro-positive to the previously kathodic spot), while the equivocal or heterodrome blaze current is probably of local post-kathodic origin (the previously kathodic spot being now strongly electro-positive to the previously anodic spot).

The presence of an unequivocal or homodrome blaze current is in my experience proof positive that the object under examination is alive.   Absence of the effect is strong presumptive evidence that the object is " dead," or rather not-living.   It may be in that paradoxical state of immobility which we characterise as latent life, and which we may not characterise as the living state, inasmuch as no sign of life is manifested, nor as dead, inasmuch as the living state can be resumed. An object in this dormant state exhibits no " blaze current " or other sign of life.   And although it has capacity of life, and cannot therefore be classed in the category of " dead " things, it is not actually living, and must therefore logically be classed in the more extensive category of not-living things.

Limiting ourselves to the unequivocal blaze current as the criterion between the living and not-living states, we may formulate the follow- ing practical rule for a summary interrogation of any given object :—

If the after-currents aroused by single induced currents of both directions are in the same direction, the object investigated is alive.

Practically, by reason of the fact that most objects of experiment are not physiologically homogeneous, this rule finds frequent applica- tion, inasmuch, as there is a favourable and an unfavourable direction of response, which occurs in the former direction, whether the excitation happen to be in the former or in the latter (*e.g.*, electrical organs, eye- ball, skin, injured tissues animal and vegetable).

In the case of objects that are physiologically homogeneous or nearly so, the after-currents to both directions of exciting current may be homodrome, *i.e.*, of the nature of unequivocal blaze currents.   In such case it generally happens that the two opposite reactions are more or less unequal, by reason of imperfect physiological homogeneity of the mass of matter under investigation.   It rarely happens that the physiological homogeneity is such that the two unequivocal blaze currents are quite equal and opposite.

So that the diagnosis of any suitable object as to its state of life or not-life rests upon the three following types of response :—

1. Both after-currents aroused by single induction shocks (or by condenser discharges) of both directions are homodrome to the exciting currents.   From which it is to be inferred that the object is living.

2. Both after-currents are in the same direction.   The object is living.

3. Both after-currents are in the polarisation direction.   The object is not-living.

Direction of exciting current	$-$	$+$
Direction of after-current (1)	⟵———	———⟶
,, ,, $(2)^a$	⟵———	⟵———
,, ,, $(2)^b$	———⟶	———⟶
,, ,, (3)	———⟶	⟵———

The three cases are indicated as above, and it should be stated that in addition to the test of direction, electromotive force (which on my plan of investigation can always be approximately ascertained) serves to make the diagnosis easy in the great majority of instances. The electromotive value in the case of an ordinary blaze current greatly exceeds that of an ordinary polarisation-current (*e.g.*, the former on vigorous seeds may reach 0·1 volt, while on the same seeds the polarisation-current similarly observed, was between 0·0005 and 0·001 volt). It is only in the case of weak or moribund seeds that there is any room for uncertainty in the answer, by reason of a weak blaze current in conflict with the weak polarisation-current. But the vitality of such seeds, although we may be unable to assert that it has fallen to the zero level, is insufficient for germination, and as tested in the incubator at 25° such seeds have to be registered as dead.

The principal points of the preceding statements may be illustrated by the following experiment, which I give as being typical; the expressions " positive " and " negative " signify that the currents respectively pass upwards from B to A, or downwards from A to B, through the seed.

Typical Experiment.—A freshly shelled out and unbruised bean set up laterally* between unpolarisable electrodes gives—

1. Blaze current in the positive direction in response to an induc-

---

* I have given this typical experiment only to represent main facts without details concerning differences according to strength of excitation, interval between successive excitations, temporary abolition by excessive excitation, recovery of capccity for reponse after injury, &c., &c. These and other points will be dealt with in a more detailed and comprehensive account of the phenomena. It should, however, be remarked at this stage that the lateral position of a bean, so that an exciting current traverses both cotyledons normally, is chosen as being the least asymmetrical and by reason of the situation of the embryo less liable to involve physiological inequality than a longitudinal disposition. The comparison of effects on the embryo proper and on the detached cotyledons shows that although all parts of the seed give the blaze effect, the latter is greater in the embryo than in the cotyledons at the outset of germination, and that in an abortive germination it disappears from the embryo sooner than from the cotyledons; *e.g.*—

Cot. 1.	Radicle.	Cot. 2.
0 ·0050	0 ·0625	0 ·0020
nil	0 ·0180	0 ·0015
0 ·0060	0 ·0170	0 ·0040

The plumule gave generally a smaller effect than the corresponding radicle. The peeled-off testa gave no blaze whatever, and was evidently dead; its polarisation counter-currents were relatively considerable. For these and other reasons I prefer to test the isolated radicle rather than the entire seed.
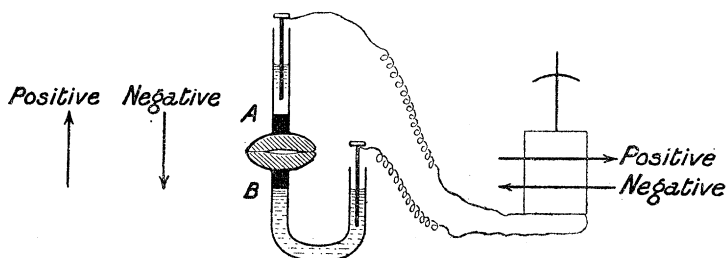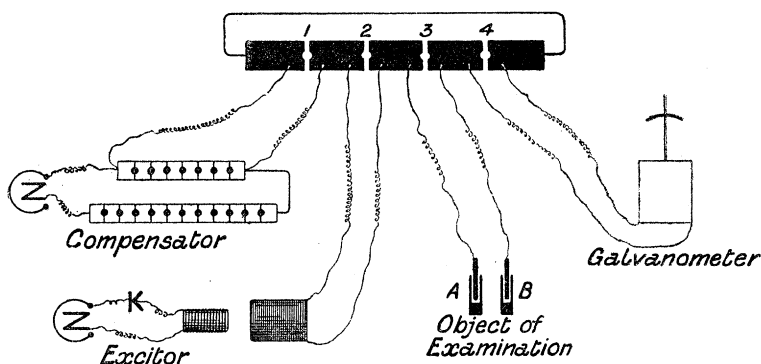
Fig. 1.

Fig. 2.

To a keyboard having four plugs and plug-holes 1, 2, 3, 4 are connected—

1. A compensator to balance any accidental current in circuit and to measure E.M.F. of reaction.
2. An induction coil to supply the stimulus, preferably a single break shock, the make being cut out.
3. The object under examination.
4. A galvanometer.

The procedure is as follows :—

With 3 and 4 unplugged any current that may be present in the object is shown by the galvanometer. Such current is balanced by manipulation of the compensator unplugged at 1. When exact compensation is obtained the galvanometer can be plugged and unplugged at 4 without any deflection from zero.

With the galvanometer plugged at 4 a single induction shock is now sent through the object (with 1, 2, and 3 unplugged). Immediately afterwards the galvanometer is unplugged, and the deflection (caused by the after-current) is noted.

The E.M.F. causing it is approximately estimated by comparison with the deflection by a known E.M.F. from the compensator.

tion shock in the positive direction ; and in the negative direction in response to an induction shock in the negative direction.

2. The same bean after removal of a horizontal slice from its under

surface B (giving therefore current of injury of positive direction) gives blaze currents in the negative direction in response to an induction shock in the positive direction (= an equivocal blaze in the polarisation direction) and to an induction shock in the negative direction (= an unequivocal blaze in the homodrome direction). If the bean is horizontally sliced at the upper surface A instead of at the lower surface B, the current of injury is negative and the blaze currents positive in response to both directions of excitation.

3. A boiled bean gives no blaze currents in either direction but only small polarisation counter-currents, in the positive direction after a negative current and in the negative direction after a positive current.

The next obvious point to be tested is the effect of anæsthetics upon the response. The results depend upon strength of excitation employed, and duration of anæsthetisation. *Cæteris paribus*, the strong effect of a strong stimulus is far more refractory to the action of an anæsthetic than the smaller effect of a weaker stimulus, and in the former case the suppression is apt to be incomplete, or when complete to be definitive. To obtain temporary suppression it is necessary to choose a sufficient but not too strong exciting current, and to anæsthetise by ether rather than by chloroform.

In a preceding paragraph it has been mentioned that a fresh vigorous seed gives a large blaze current, whereas a stale or moribund seed gives little or no response. The next step was obviously to compare similar seeds submitted to various enfeebling modifications, as well as different crops of similar seeds, the electrical tests being controlled by parallel germination tests.

The first and most readily effected comparison is that between the reactions of fresh seeds and of the same seeds killed by boiling. The result of this comparison is unmistakable and invariable. Fresh seeds, giving unequivocal blaze currents with an E.M.F. of 0·01 to 0·10 volt, give no blaze currents whatever after they have been boiled, but only polarisation counter-current with an E.M.F. of 0·0005 to 0·0020 volt. The seeds upon which I have made this test have been leguminous seeds, such as shelled beans and peas boiled in water, and the kernels of stoned fruits such as cherries, plums, and peaches boiled in their protected state.*

---

* The reaction is abolished at a temperature considerably below that of boiling water; *e.g.*, at a temperature of between 40° and 50° of a warm moist chamber. Miss S. C. M. Sowton has carefully investigated this point and that relating to the effect of anæsthetics, by aid of photographic records, which are in fact indispensable in connection with these two points. It is also abolished by congelation (at − 3° to − 5°), which causes a sudden large electromotive effect at this point. On recovery of normal temperature no blaze can be obtained, and on recongelation there is no electromotive effect at the critical temperature.

My attention at this early stage of the inquiry has been chiefly directed to the deterioration of seeds with age and to the comparison *inter se* of sets of seeds of certificated years by means of the germination test and of the blaze test used quantitatively.

I selected beans as being of suitable bulk and readily obtainable, and I have to thank Messrs. Sutton for supplying me with many different samples of known dates.   After a considerable number of trials upon entire seeds variously orientated between the electrodes, soaked in water of various temperatures for various periods, and upon the several isolated parts of seeds, I fixed upon the following procedure as conveniently yielding series of numerical results comparable *inter se.*

The " dry " beans are first soaked in water for twelve hours in an incubator adjusted at 25° C., then laid upon moist flannel and replaced in the incubator for examination during the next day.   Each bean was then peeled and split, and the radicle was carefully broken off and placed between the clay pads of the electrodes (fig. 1) so that the uninjured apex was in contact with the upper electrode A, and the fractured base with the lower electrode B.   With this position we have a " positive " current of injury from B to A, and have to expect a " negative blaze " current from A to B in response to excitation.   In order that the response shall be " unequivocal," the exciting current is taken of negative direction.   To ensure maximal effect a strong current is taken, viz., a break induction shock at 10,000 units of Berne c⸍͞ And inasmuch as a current of such strength repeated for a second time shortly after a first trial produces little or no effect, and even when repeated after a considerable interval a much smaller effect than at its first application, it is necessary to take for the purpose of numerical comparison exclusively the values obtained at first trials.   To this end it may be necessary to shunt the galvanometer to such an extent that the blaze effect to be expected from the first excitation shall give a deflection within the scale ; a second trial when the first trial has given a deflection off scale, is of no value whatever.

By adoption of uniform conditions on these lines, comparisons may profitably be made between different series of results.   But at this early stage of the inquiry, not knowing what conditions it might be advisable to select, I have been forced to vary them in tentative directions, by variation of strength of excitation,* of length of soakage, and

---

* To avoid exhaustion by strong currents, and to obtain a regularly repeated series of effects, I find that condenser discharges are more suitable than induction shocks. The discharge of 1 microfarad charged by two Leclanché cells (= about 40 ergs) usually gives a convenient normal effect upon which to investigate the effects of temperature variations, and of anæsthetic vapours.

I also find it preferable to use the radicle some hours after it has been broken off, by which time its current of injury has subsided, and blaze currents are obtainable in both directions.

of interval between soakage and examination.   These departures from strict uniformity, while affording necessary information, restrict legitimate comparisons to data within each particular table ; comparisons from table to table may not be safely made.

FIG. 3.
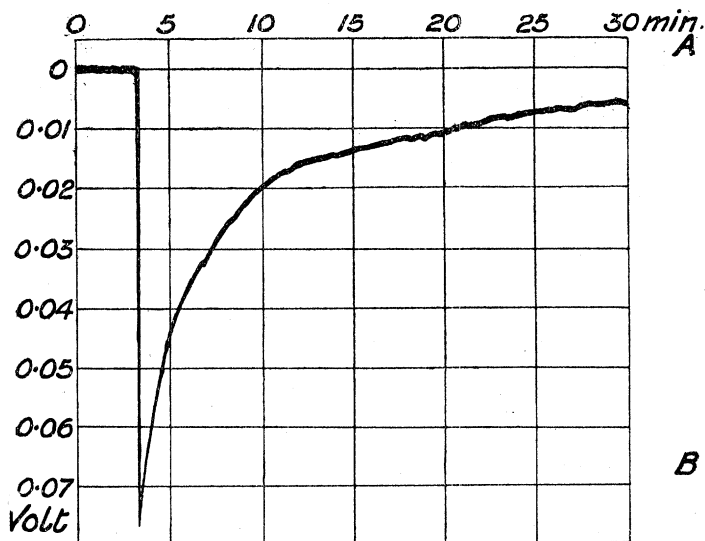
Photographic record of an unequivocal blaze current of the radicle of a bean (1900 crop).   Excitation by a strong break induction shock in the A to B or negative direction.   Homodrome response of 0·075 volt.

With regard to the germination tests, they have been carried out for the most part upon similar lots taken from the same parcels as those from which other seeds were taken to be electrically tested as described above.   This latter required each seed to be broken up and rendered unfit for germination.   I think that the parallel pair of tests made upon twin lots of different individual seeds is nearly as conclusive as if both tests had been made upon the same individual seeds—*vide, e.g.,* Table I.   Nevertheless, to meet the criticism that this proof is not conclusive, I have obtained three series of data in which the electrical and germination tests were carried out upon the same individual beans. In all three series I previously determined the coefficient of each intact seed by the blaze test ; the germination test was subsequently carried out in one series at Kew under the supervision of Sir W. Thiselton-Dyer (Table VII) ; in a second series at Chelsea under the supervision of Professor Farmer (Table VIII) ; and in the third series by myself in my own laboratory (Table IX).   But I find it far less satisfactory to

make the electrical test upon an entire seed with unknown local bruises received during its fresh state or in course of preparation, than upon a previously protected portion of the seed with an obvious injured end, as in the case of the radicle freshly exposed by separation of the cotyledons, and nipped off at its base immediately* before an observation is made.   Moreover, in the former case the current-density is smaller, the blaze effects are relatively less considerable, and the polarisation counter-effects relatively more considerable. And, finally, irregularities due to irregular distribution of water† are more liable to occur in the comparatively large mass of an entire seed than in the comparatively small mass of its removed radicle.

Table I.—Comparison between Radicles of Bean Embryos of the years 1860 and 1899.   In each case the seeds were soaked in water at room temperature (15° to 18°) for 24 hours before experiment.

N.B.—In these and all subsequent experiments the radicles were disposed as described in the text, with uninjured apex to electrode A and fractured base to electrode B (fig. 1).   Excitation is by a single break induction shock of a Berne coil, fed by two Leclanché cells, 10,000 units, negative direction from A to B. The blaze current is in the same (negative) direction, *i.e.*, is unequivocal.

The galvanometer was shunted to such an extent that $\frac{1}{100}$th volt gave a deflection of 4 cm. of scale.   At this degree of sensitiveness polarisation currents are practically illegible.

Seed.	1860.	Seed.	1899.
No. 1	0	No. 11........	− 0·0750
„ 2	0	„ 12........	− 0·0400
„ 3	0	„ 13........	− 0·0700
„ 4	0	„ 14........	− 0·0600
„ 5	0	„ 15........	− 0·0350
„ 6	0	„ 16........	− 0·0350
„ 7	0	„ 17........	− 0·0100
„ 8	0	„ 18........	− 0·0175
„ 9	0	„ 19........	− 0·0200
„ 10	0	„ 20........	− 0·0075
Average blaze..	0	..	− 0·03700
Germination ..	0 per cent.	..	100 per cent.

* Or some hours previously (*vide* note on p. 84), although in such case the radicle has appeared to be more rapidly exhausted by repeated stimulation.

† Beans soaked unequally (at the end of twenty-four hours) give blaze currents from more soaked to less soaked portions and not *vice versâ*.   A bean that is left for several days in water becomes water-logged and finally decomposes. Such a " drowned " bean will not germinate nor give any blaze whatever.   A half-drowned bean gives blaze only towards the drowned (or more soaked) half.

Seed.	1899 (after three days in water).	Seed.	1899 (after four weeks soaking in water, *i.e.*, rotting).
No. 21........	−0·0300	No. 31........	0
,, 22........	−0·0150	,, 32........	0
,, 23........	−0·0200	,, 33........	0
,, 24........	−0·0200	,, 34........	0
,, 25........	−0·0250	,, 35........	0
,, 26........	−0·0100	,, 36........	0
,, 27........	−0·0100	,, 37........	0
,, 28........	−0·0250	,, 38........	0
,, 29........	−0·0175	,, 39........	0
,, 30........	−0·0200	,, 40........	0
Average	−0·01925	..	0

Remarks.—The seeds of 1860 gave no blaze currents, nor any sign of germination. All those of 1899 gave blaze currents and germinated vigorously. In consequence of prolonged immersion under water, other seeds of 1899 became water-logged, and finally gave no blaze current nor sign of germination.

Four weeks is not a minimum time. I have found beans to be without exception completely drowned at the end of 5 days' immersion in water at 25°, and this period has probably not been a minimum. The shortest time of soakage after which I have observed the blaze has been one hour.

Table II.—Comparison between Beans of the years 1895 to 1899. Forty-eight hours' soakage at room temperature. Averages of 10 seeds of each year. Germination test not made.

	1895.	1896.	1897.	1898.	1899.
Weight of 10 seeds—	grammes.				
Before soaking ...	6·2	5·8	6·2	3·3	4·8
After soaking	13·9	7·6	12·5	6·4	10·5
Average blaze..	0·0014	0·0036	0·0043	0·0052	0·0170

Table III.—Do., do.   Time of soakage not noted (? 36 hours). October 15.

	1895	1896	1897	1898	1899
Average blaze	0·0008	0·0027	0·0031	0·0035	0·0086

Table IV.—Do., do., but a different series.

	1895	1896	1897	1898	1899
Average blaze	0·0030	0·0028	0·0033	0·0240	0·0260

Table V.—Another series of three years (dates not known with certainty).

	1896 ?	1897 ?	1899.
Average of 10 observations—			
On entire seeds	0·0002*	—	0·0014 (irregular)
On separated radicles.....	0·0007*	0·0028	0·0056 (regular)
Germination value	55 per cent.	75 per cent.	90 per cent.

Table VI.—Beans (radicles only) of two years, 1895 and 1900.

	1895. Soaked for 3—5 hours.	1900. Soaked for 3—5 hours.	1900. Soaked for 12 hours.
Average of 10 observations ..	0·0016 irregular	0·0120	0·0510†
Germination value	.. "weak"	100 per cent. "strong"	100 per cent. "strong"

Table VII.—Twelve Intact Beans of 1895, soaked in water at 24° for 12 hours, then laid on wet flannel in incubator for a further 12 hours at 24°, measured electrically on December 17, and forwarded to Kew for independent test by germination. I have to thank Sir W. Thiselton-Dyer for the account of their subsequent behaviour.

	Blaze reactions.	Subsequent behaviour at Kew.	
		Date of germination.	Condition.
Bean No. 1	0·0050	December 28	Weak.‡
„ 2	0·0025	Failed	
„ 3	0·0175	December 22	Strong.
„ 4	0·0125	December 27	Moderate.
„ 5	0	Failed	
„ 6	0·0100	December 22	Strong.
„ 7	0	Failed	
„ 8	0·0100	December 25	Strong.
„ 9	0	Failed	
„ 10	0·0050	December 31	Weak.‡
„ 11	0·0100	December 24	Strong.
„ 12	0·0100	December 24	Strong.

* The responses were small and irregular, and in the case of the entire seeds the arithmetical mean of the series of 10 is of wrong—*i.e.*, of polarisation—direction. The electrical resistance of all the radicles was tested and found to be within the limits of 100,000 and 200,000 ohms.

† The average value obtained from 20 entire beans was 0·0040.
The maximum value observed on the radicles of 1900 was 0·1200.

‡ Those marked weak are not likely to get beyond the cotyledon stage.

Table VIII.—Intact Beans of 1895 and of 1900, tested Electrically by
Dr. Bullot, and subsequently forwarded to Professor Farmer at
Chelsea for an independently Germination Test.

1895.	Accidental current.	Electrical response.		Germination.
		Exc. +.	Exc. —.	
No. 1	− 0 ·0018	− 0 ·0003	+ 0 ·0017	None.
,, 2	− 0 ·0023	− 0 ·0012	− 0 ·0021	,,
,, 3	− 0 ·0004	+ 0 ·0004	+ 0 ·0003	,,
,, 4	− 0 ·0014	− 0 ·0002	+ 0 ·0003	,,
,, 5	− 0 ·0077	+ 0 ·0008	+ 0 ·0022	,,
,, 6*	− 0 ·0022	− 0 ·0001	+ 0 ·0002	,,
,, 7*	− 0 ·0030	− 0 ·0002	+ 0 ·0002	,,
,, 8	+ 0 ·0009	+ 0 ·0038	− 0 ·0045	,,
,, 9	− 0 ·0100	+ 0 ·0011	+ 0 ·0070	,,
,, 10	− 0 ·0020	+ 0 ·0005	− 0 ·0038	,,
1900.				
No. 11	+ 0 ·0010	+ 0 ·0125	− 0 ·0075	Yes.
,, 12*	+ 0 ·0005	0	0	No.
,, 13	− 0 ·0120	+ 0 ·0065	+ 0 ·0020	Yes.
,, 14	− 0 ·0205	+ 0 ·0013	+ 0 ·0100	,,
,, 15	+ 0 ·0025	− 0 ·0040	− 0 ·0125	,,
,, 16	− 0 ·0070	− 0 ·0010	+ 0 ·0046	No.
,, 17	− 0 ·0105	+ 0 ·0060	+ 0 ·0024	Yes.
,, 18	− 0 ·0025	+ 0 ·0056	− 0. 0050	No.
,, 19	− 0 ·0067	+ 0 ·0012	+ 0 ·0044	Yes.
,, 20*	− 0 ·0025	− 0 ·0003	+ 0 ·0003	No.

With regard to the second series Professor Farmer remarks that he
does not attach much value to it, since the seeds were kept cool at first
and otherwise more might have germinated. Nos. 14 and 18, according
to the blaze test, should have germinated, but did not do so. A seed
giving blaze may fail to germinate, but I have as yet met with only one
case of a seed giving no blaze, and subsequently germinating (No. 4 of
Table X).

* Nos. 6, 7, 12, and 20 had been previously boiled.

Table IX.—Intact Beans of 1895 and of 1900 tested Electrically and subsequently by Germination Results.

| 1895. | Electrical response. | | Germination. |
	Exc. 10,000 ÷.	Exc. 10,000 −.	
No. 1	− 0 ·0009	− 0 ·0010	None.
,, 2	+ 0 ·0002	+ 0 ·0006	,,
,, 3	− 0 ·0004	− 0 ·0003	,,
,, 4	0	+ 0 ·0010	,,
,, 5	− 0 ·0007	− 0 ·0002	,,
,, 6	+ 0 ·0007	+ 0 ·0015	,,
,, 7	0	+ 0 ·0008	,,
,, 8	− 0 ·0008	− 0 ·0010	,,
,, 9	− 0 ·0006	+ 0 ·0003	,,
,, 10	0	+ 0 ·0014	,,
1900.			
No. 1	+ 0 ·0054	− 0 ·0020	Yes.
,, 2	+ 0 ·0021	− 0 ·0030	,,
,, 3	+ 0 ·0032	− 0 ·0022	,,
,, 4	+ 0 ·0042	− 0 ·0015	,,
,, 5	+ 0 ·0025	− 0 ·0010	,,
,, 6	+ 0 ·0008	− 0 ·0042	,,
,, 7	− 0 ·0008	+ 0 ·0004	No.
,, 8	+ 0 ·0004	− 0 ·0006	Yes.
,, 9	+ 0 ·0165	− 0 ·0104	,,
,, 10	+ 0 ·0025	− 0 ·0015	,,

In my hands and in those of Professor Farmer the germination (in earth) of this 1895 sample was nil. The electrical response was throughout small and irregular. A further test of germination made on moist flannel in the incubator at 25° gave 40 per cent. as the proportion of seeds exhibiting any sign of activity.

The second series of this table gave a very striking and satisfactory result. Of the ten seeds all but the seventh had given clear electrical signs. They were planted in two regular rows and left undisturbed in a greenhouse for one month. At the end of this time the box contained two rows of nine vigorous plants with a gap opposite the number 7.

Table X.—Beans of 1900 crop (*Phaseolus?*) soaked in water for 12 hours, then incubated for 12 hours. Tested electrically (+ Br. 10000) on January 28. Incubated on flannel and observed on January 31 and on February 4, when they were again tested electrically.

	January 28. Blaze.	January 31. Germin.	February 4. Radicle.	Blaze.
No. 1	> + 0·0050 volt.	Yes	Large	+ 0·0124
,, 2	0	No	None	− 0·0002
,, 3	+ 0·0035 ,,	Yes	Small	− 0·0023
,, 4	− 0·0002 ,,	No (App. Feb. 2)	Mod.	+ 0·0006
,, 5	+ 0·0013 ,,	Yes	Mod.	− 0·0006
,, 6	> + 0·0050 ,,	Yes	Large	+ 0·0050
,, 7	− 0·0005 ,,	No	None	− 0·0002
,, 8	− 0 ,,	No	None	0
,, 9	> + 0·0050 ,,	Yes	Large	> + 0·0100
,, 10	> + 0·0050 ,,	Yes	Large	+ 0·0080

CONCLUSION.

The physiological character of the blaze reaction is proved (1) by the influence of raised temperature; (2) by its general parallelism with germination tests; (3) by the influence of lowered temperature; (4) by the influence of anæsthetics; (5) by the influence of strong electrical currents; (6) by the absence of blaze and failure of germination in the case of water-logged seeds. In every instance a bean giving no blaze, gave subsequently no sign of germination.

There has been throughout these first observations a general, but not faultless, correspondence, as regards magnitude, between the blaze reaction and the germinative activity. The correspondence is such as to make good the principal fact that the blaze reaction is a sign of life, and that its magnitude is some measure of what we designate as "vitality." The defects of correspondence may have been due to irregularities in the results of the blaze test, or of the germination test, or of both tests. As regards great differences of vitality, both tests are obviously and in every case concordant, both replying by an indubitable "yes" or "no" to the question whether there is blaze and germination. As regards the lower degrees and the smaller differences of vitality, the chances of disagreement between the two tests are obviously greater. As regards the electrical test, it is more difficult to take the measure upon the entire seed than upon its isolated radicle. As regards the germination test, it is not always easy to ensure identical and optimum conditions.

Fresh and vigorous seeds manifest a large blaze response (0·0500 volt or more), and germinate strongly. Older and less vigorous seeds mani-

fest a smaller blaze (0·0100 volt or less), and a less active germination. Still older seeds, incapable of germination under even the most favourable conditions, manifest still smaller blaze (0·0010 volt or less), and finally none at all, or the small counter-effect due to polarisation (0·0005 volt more or less).

The series of communications, of which the present communication is the 12th, is as follows :—

1. " On the Retinal Currents of the Frog's Eye, Excited by Light and Excited Electrically," 'Roy. Soc. Proc.,' vol. 66, p. 327, March 29, 1900 ; 'Phil. Trans.,' p. 123, 1900.
2. " Action Électromotrice de la Substance Végétale consécutive à l'Excitation Lumineuse," 'Comptes Rendus de la Société de Biologie,' p. 342, March 31, 1900.
3. " The Electrical Effects of Light upon Green Leaves," 'Roy. Soc. Proc.,' vol. 67, p. 129, June 14, 1900.
4. " Four Observations concerning the Electrical Effects of Light upon Green Leaves," 'Physiol. Soc. Proc.,' June 30, 1900.
5. " Le Dernier Signe de Vie," 'Comptes Rendus de l'Académie des Sciences,' September 3, 1900.
6. " On the Excitability of Nerve : its last Sign of Life," 'Proceedings of the Neurological Society,' October 25, 1900 ; " Brain," p. 542.
7. " The Eyeball as an Electrical Organ," 'Physiol. Soc. Proc.,' November 10, 1900.
8. " On the ' Blaze Currents ' of the Frog's Eyeball," 'Roy. Soc. Proc.,' vol. 67, p. 439, December 6, 1900 ; 'Phil. Trans.,' 1901.
9. " The Frog's Skin as an Electrical Organ," 'Physiol. Soc. Proc.,' December 8, 1900.
10. " Action Électromotrice des Feuilles Vertes sous l'Influence des Lumières Rouge, Bleue et Verte," 'Comptes Rendus de la Société de Biologie,' December 22, 1900.
11. " Le Premier Signe de Vie," 'Comptes Rendus de l'Académie des Sciences,' December 24, 1900.

" On a New Manometer, and on the Law of the Pressure of Gases between 1·5 and 0·01 Millimetres of Mercury." By LORD RAYLEIGH, F.R.S. Received January 15,—Read February 21, 1901.

(Abstract.)

The new manometer, charged with mercury, is capable of measuring small pressures to an accuracy of 1/2000 mm. of mercury. This may be compared with the ordinary manometer, read with the aid of a cathetometer, which is capable, according to Amagat, of an accuracy of 1/100 mm. at most.

With this instrument the behaviour of nitrogen, hydrogen, and
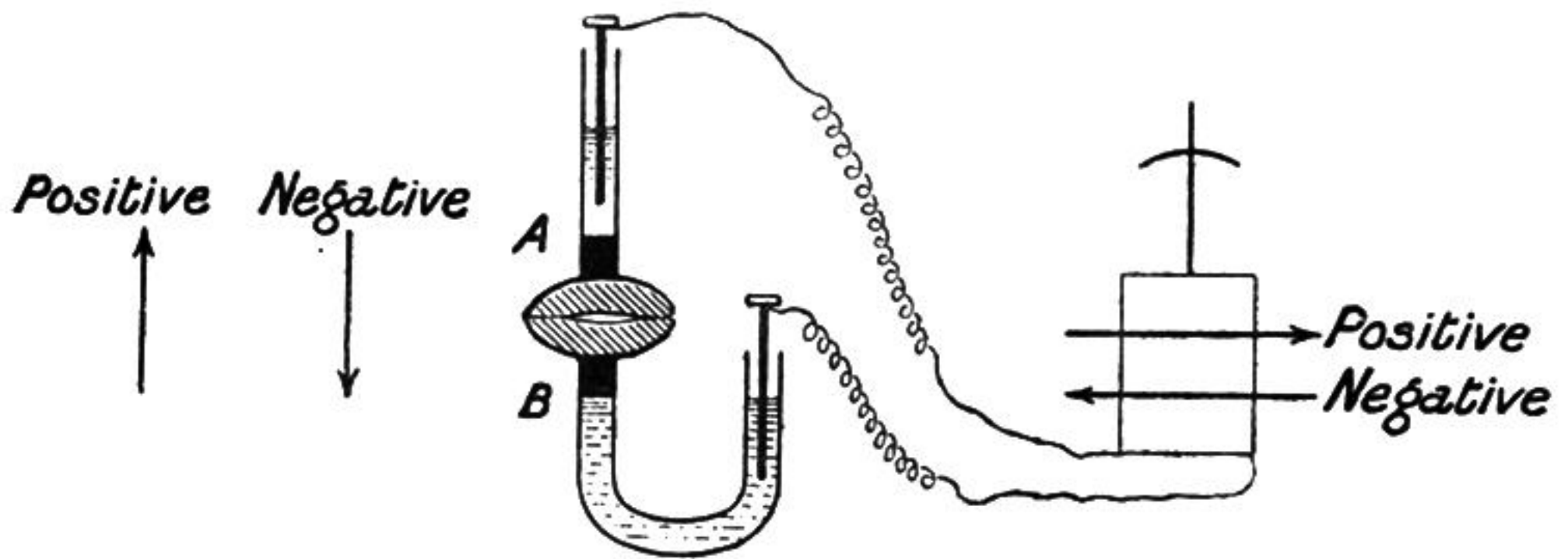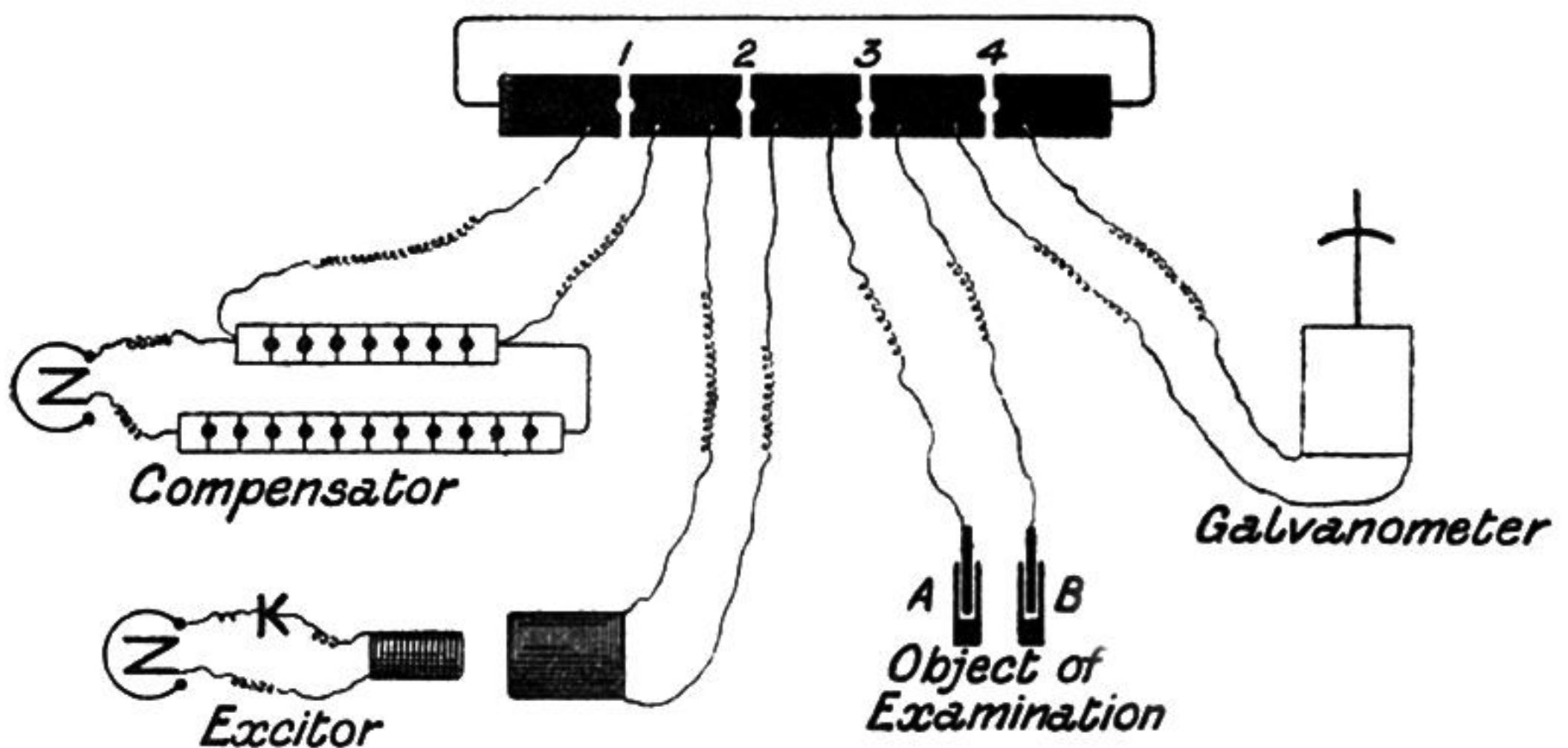
FIG. 1.

FIG. 2.

To a keyboard having four plugs and plug-holes 1, 2, 3, 4 are connected—

1. A compensator to balance any accidental current in circuit and to measure E.M.F. of reaction.

2. An induction coil to supply the stimulus, preferably a single break shock, the make being cut out.

3. The object under examination.

4. A galvanometer.

The procedure is as follows :—

With 3 and 4 unplugged any current that may be present in the object is shown by the galvanometer. Such current is balanced by manipulation of the compensator unplugged at 1. When exact compensation is obtained the galvanometer can be plugged and unplugged at 4 without any deflection from zero.

With the galvanometer plugged at 4 a single induction shock is now sent through the object (with 1, 2, and 3 unplugged). Immediately afterwards the galvanometer is unplugged, and the deflection (caused by the after-current) is noted.

The E.M.F. causing it is approximately estimated by comparison with the deflection by a known E.M.F. from the compensator.